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Arctic climate responses to mid-latitude aerosol emissions: Combining modelling and observational evidence to identify critical processes

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Previous studies using the Earth system model NorESM have shown that changes in aerosol particle emissions in various geographical regions in the northern mid-latidtudes result in significant temperature responses in the Arctic, which are amplified compared to the global mean.

We aim to understand what triggers these polar temperature responses and which processes amplify the initial response. Here, we present results from the first part of this work, namely model evaluation in the Arctic region. The goal of this analysis is to identify critical processes driving the Arctic climate response in NorESM to mid-latitude aerosol emission changes. To this end, we use new observational datasets, both remote and in-situ, of aerosol size distribution, cloud fraction, aerosol optical depth, surface radiative fluxes.

Preliminary results show that Arctic sea ice trends are much weaker in the modelling framework compared to observations. Modelled cloud fractions are higher than observed, especially at lower altitudes. This is in line with a tendency to lower surface solar radiation in the model output compared to observations at numerous sites throughout the Arctic region. There are indications that in NorESM, lower-latitude aerosol particles reach the Arctic region predominantly through the free troposphere, which is not substantiated by remote observations of aerosol extinction. Total aerosol number concentrations in NorESM1 are in good agreement with in-situ observations at five surface sites, but particle sizes are smaller than observed, especially during winter.

Our findings suggest that aerosol sizes in the Arctic are underestimated compared to observations, in particular during winter months, and thus that aerosol activation and subsequent indirect aerosol effects in the Arctic in NorESM1 might be larger than one would expect from observed size distributions. This result also has implications for the Arctic surface energy balance, which may directly impact sea ice extent. The Arctic surface energy balance was identified as linearly related to the magnitude of Arctic amplification in various CMIP5 models.